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基于深度学习和线结构光的焊缝检测系统

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在工业4.0智能制造的时代背景下，工业智能机器人产业市场呈现爆炸式增长势头，其中重要的一个应用方向为自动激光焊接。为了让机器人精准的执行焊接任务，需要搭配视觉传感器和视觉算法来完成焊缝的检测和跟踪任务。本系统采用线结构光传感器，可以在焊接时复杂的光线背景下，准确的获取工件表面的激光条纹照片。考虑到焊缝检测的本质是特征点的检测，因此本工作采用基于特征点的目标检测网络CenterNet作为焊缝检测网络的主体结构。我们从近5万张焊接时采集得到的激光条纹图片中，选取了2208张具有代表性的焊缝图片，共包括拼接，外角接，内角接，搭接，全搭五种焊缝类型。并人工对图片进行标注。在测试集上，模型的焊缝类型分类准确率为98.4%，平均焊缝定位误差为0.07031mm，99%的测试集样本的定位误差小于0.2mm。在自动焊接过程中，模型的推理速度决定了闭环控制的调整频率，也就影响了最终的控制精度。因此本工作针对本系统中深度学习模型的部署环境，对模型结构和部署方式进行了针对性的优化。在测试了多种不同特征提取网络的推理速度和精度后，选取Effcient-Net b0网络作为特征提取网络，并针对Intel的CPU硬件环境，基于OpenVINO平台来进行深度学习模型的部署，最终模型的推理时间为7.5ms，满足实时性要求。

关键词：焊缝检测；深度学习；线结构光

Weld Detection System Based on Deep Learning and Line Structured Light

In the era of Industry 4.0 intelligent manufacturing, the industrial intelligent robot industry market has shown an explosive growth momentum, and an important application direction is automatic laser welding. In order for the robot to accurately perform the welding task, it is necessary to use the vision sensor and vision algorithm to complete the welding detection and tracking task. The system uses a line structured light sensor, which can accurately obtain laser photos on the surface of the workpiece under the complex light background during welding. Considering that the essence of weld detection is the detection of feature points, this work adopts the target detection network CenterNet based on feature points as the main structure of the weld detection network. From nearly 50,000 laser images collected during welding, we selected 2,208 representative weld images, including five types of welds: splicing, outer fillet joint, inside fillet joint, lap joint, and full lap joint. and manually annotate the images. On the test set, the model's weld type classification accuracy is 98.4%, the average weld location error is 0.07031mm, and 99% of the test set samples have a location error of less than 0.2mm. In the automatic welding process, the inference speed of the model determines the adjustment frequency of the closed-loop control, which also affects the final control accuracy. Therefore, in this work, the model structure and deployment method are optimized for the deployment environment of the deep learning model in this system. After testing the inference speed and accuracy of a variety of different feature extraction networks, the Effcient-Net b0 network is selected as the feature extraction network, and the deep learning model is deployed based on the OpenVINO platform for Intel's CPU hardware environment. The inference time of the final model is 7.5ms, meeting the real-time requirements.

Key words: weld detection；deep learning；line structured light